

3/8/14

# The Heavy Flavor Tracker of STAR experiment

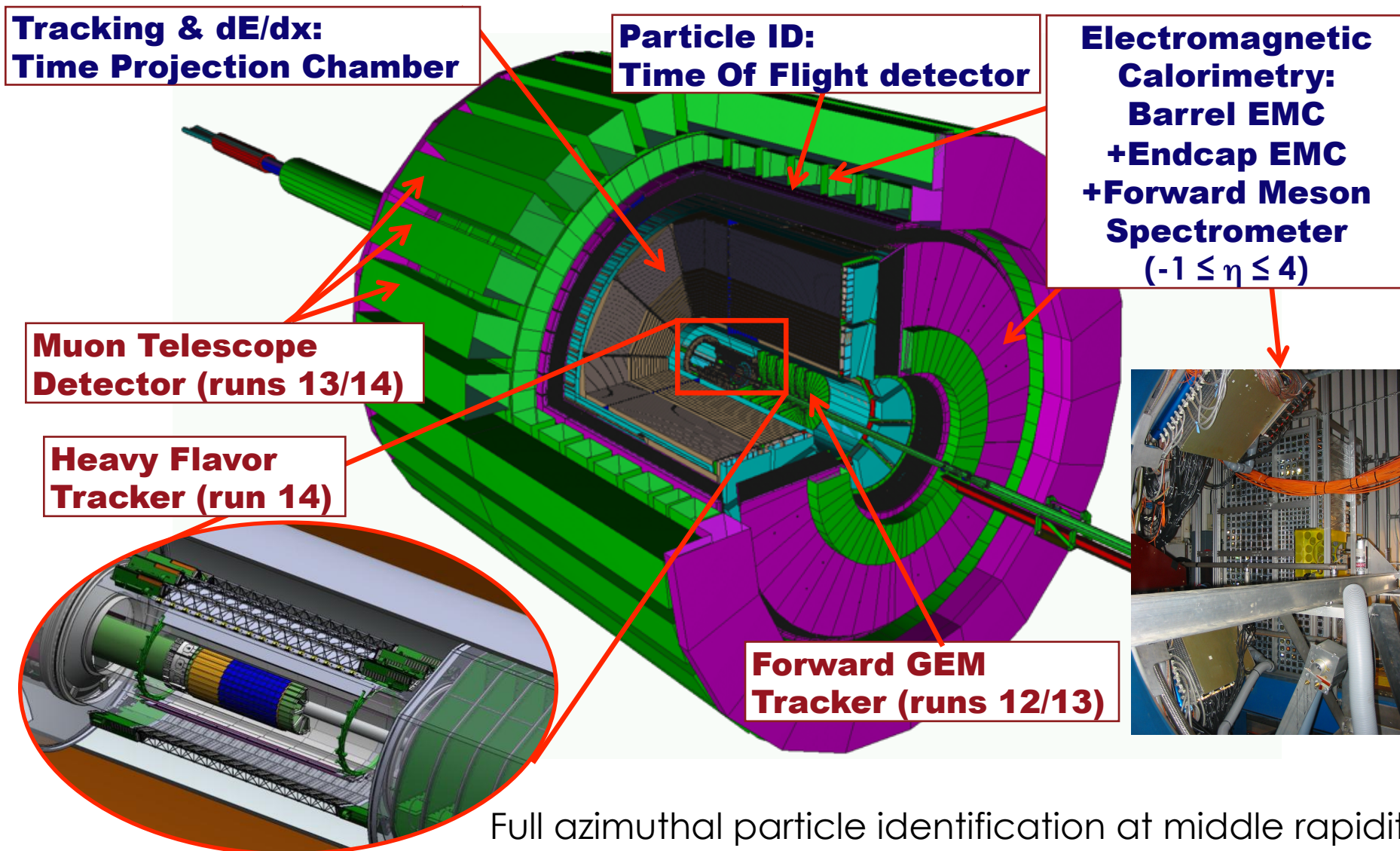
Jonathan Bouchet (KSU), for the  
STAR collaboration

# Talk Outline

- The HFT (Heavy Flavor Tracker) detector in the STAR experiment at RHIC facility of BNL
- HFT detector:
  - physics goals
  - requirements
  - design and characteristics
- (anticipated) Physics performance
- Summary

# STAR detector overview

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# New physics direction for STAR heavy ion program

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## ■ Heavy Flavor :

- $\text{Mass}_{b,c} > T_c, \Lambda_{\text{qcd}}, M_{u,d,s}$

- Early produce

- Conserve in total number

- Less influenced

- Good probe to QGP

Open heavy Flavor → **HFT**

Heavy quarkonium

→ **MTD**

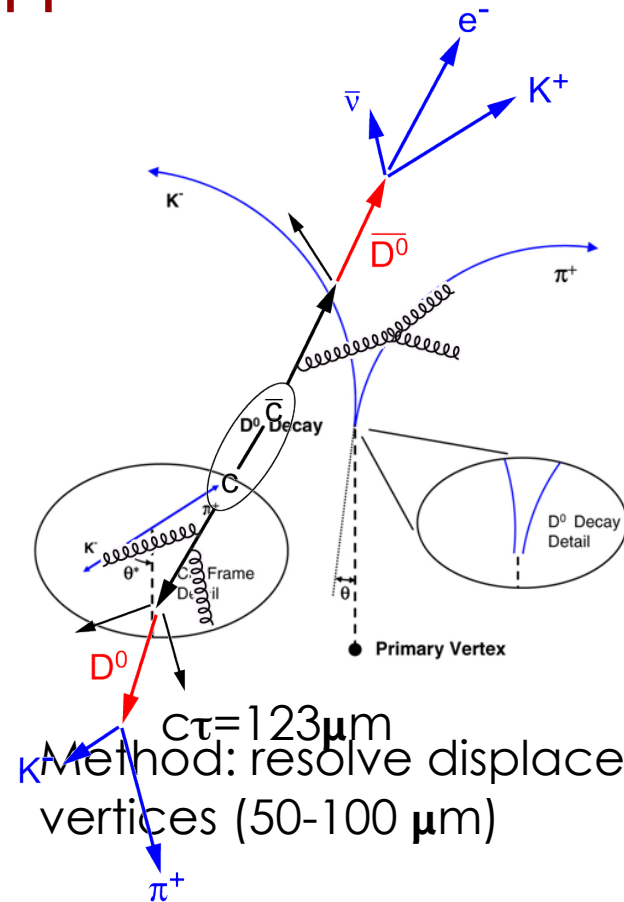
## ■ Thermal dilepton :

- QGP signal

- Probing the temperature of the medium

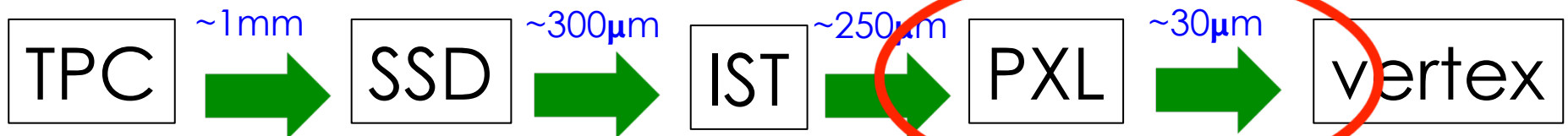


## 5



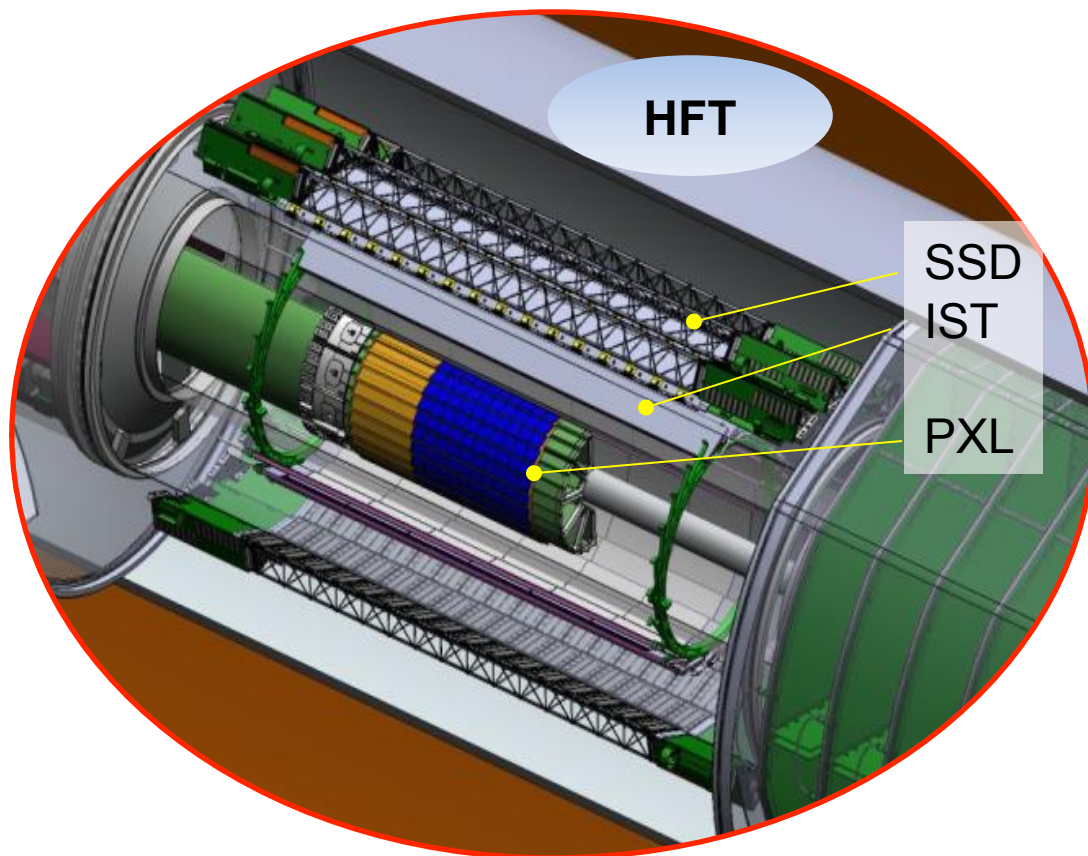
Detect charm decays with small  $c\tau$ ,  
including  $D^0 \rightarrow K \pi$

We track inward from the TPC with graded resolutions:



# Heavy Flavor Tracker HFT

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- PXL : two layers close to the beam pipe
  - New monolithic active pixel sensors (MAPS) technology
- SSD : existing single layer detector
  - double sided strips (electronics upgraded)
- IST : one layer of silicon strips along the beam direction, guiding the tracks from the SSD through PXL detector
  - proven silicon pad technology

subsystem	Radius [cm]	technology	Hit resolution : $R/\phi - Z$ [ $\mu\text{m}$ ]	Thickness [% $X_0$ ]
SSD	22	Double sided silicon strips	20 - 740	1
IST	14	Silicon strips pad sensors	170 - 1700	<1.5
PXL	2.7 ; 8	Active pixels CMOS	12 - 12	0.4 per layer

# PXL Requirements & design choices

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## Requirements

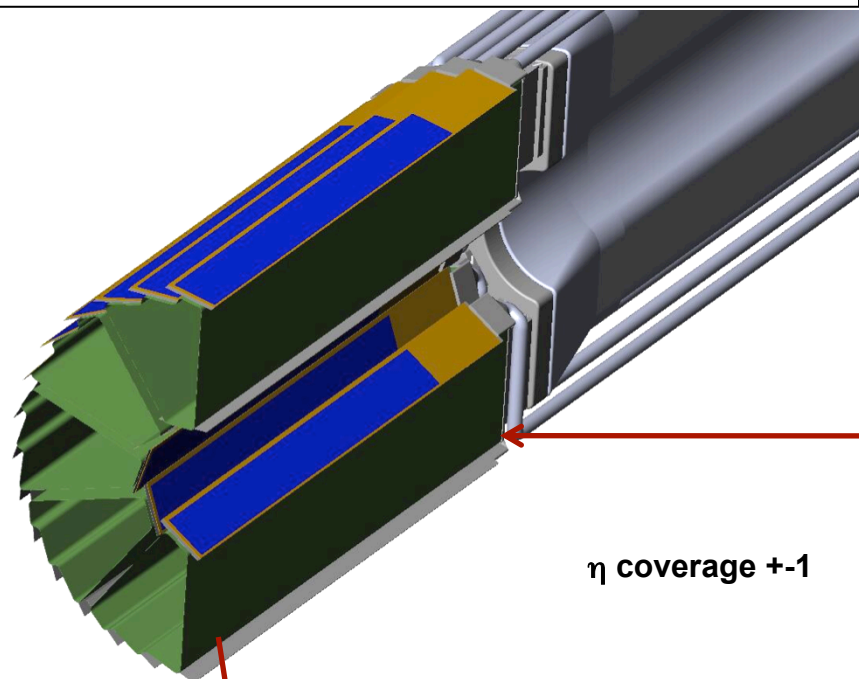
- $-1 \leq \eta \leq 1$ , full  $\phi$  coverage (TPC coverage)
- $\leq 50 \mu\text{m}$  DCA pointing resolution required for 750 MeV/c kaon
  - Two or more layers with a separation of  $> 5 \text{ cm}$ . Close to beam.
  - Pixel size of  $\leq 30 \mu\text{m}$
  - Radiation length as low as possible but should be  $\leq 0.5\%$  / layer (including support structure).  
The goal is  $\sim 0.4\%$  / layer
- Integration time of  $< 200 \mu\text{s}$
- Sensor efficiency  $\geq 99\%$  with accidental rate  $\leq 10^{-4}$ .
- Survive radiation environment.

## Choices

- Air cooling – room temperature operation
- Thinned silicon sensors ( $50 \mu\text{m}$  thickness)
  - MAPS (Monolithic Active Pixel Sensor) pixel technology
  - power dissipation  $\sim 170 \text{ mW/cm}^2$  (integration time  $< 200 \mu\text{s}$ ) [digital output]
- Quick extraction/replacement (1 day) with 20 mm envelope [4 copies]

# PXL detector design

Carbon fibre sector tubes (~200 $\mu$ m thick)



$\eta$  coverage  $\pm 1$

Ladder with 10 MAPS sensors (~2 $\times$ 2 cm each)

RDO buffers/  
drivers

MAPS

Aluminum conductor Ladder Flex Cable

20 cm

End view

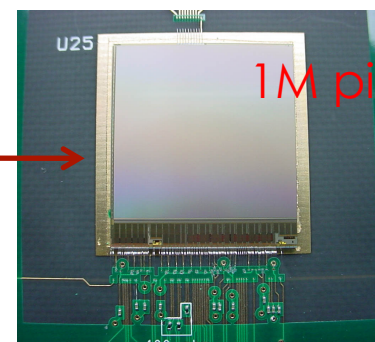
8 cm radius

2.5 cm radius

Inner layer

Outer layer

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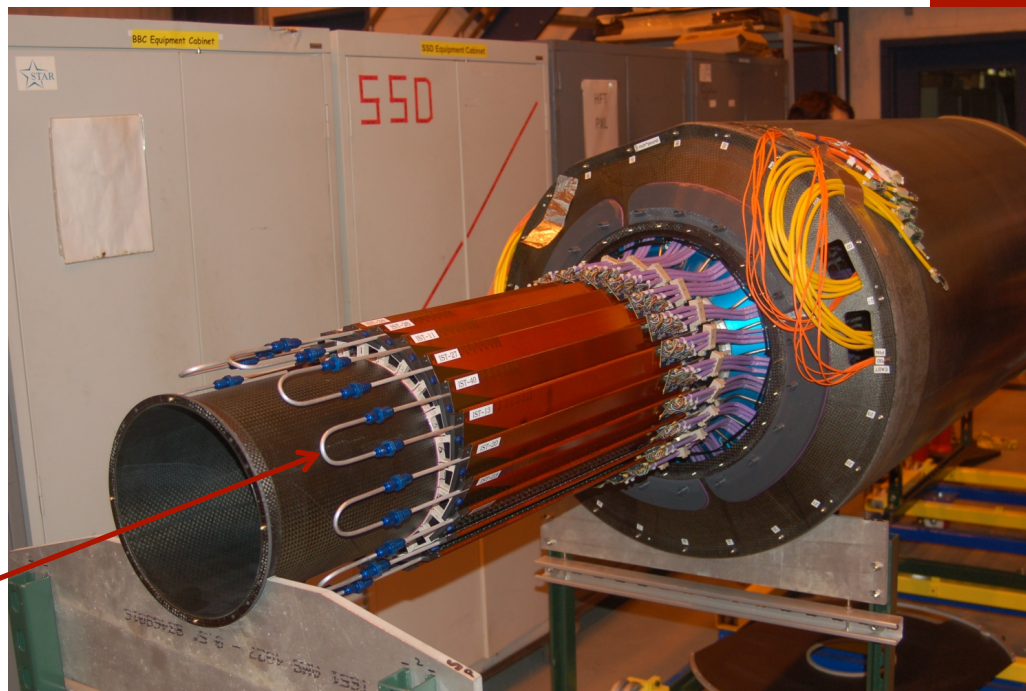
MAPS  
sensor



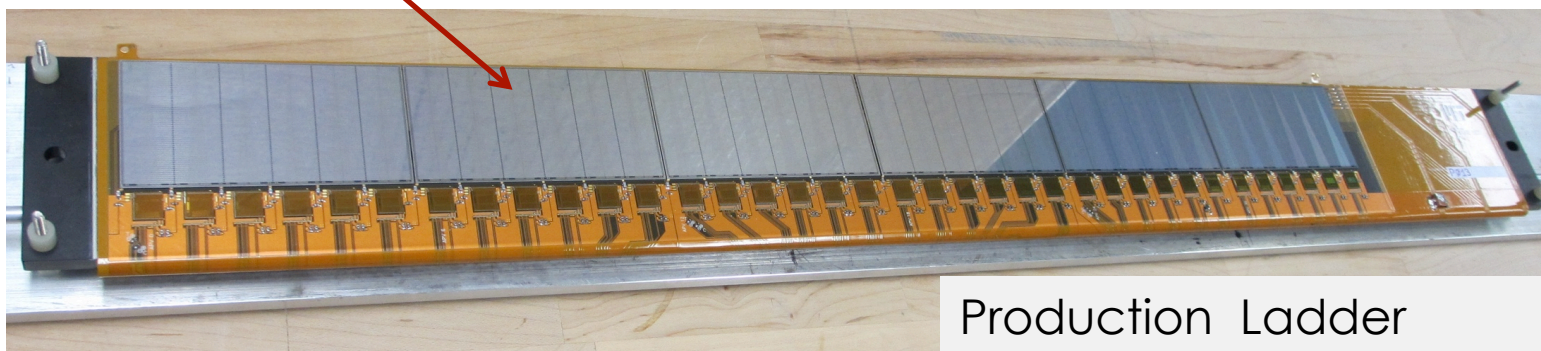
# Intermediate Silicon Tracker (IST)

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- 24 ladders 50 cm long
- At 14 cm
- Si pad detector  $.6 \times .6$  mm pads
- 24 APV hybrids per ladder for readout
- Liquid cooling
- $<1.5\%$  radiation length



24 ladders, liquid cooling.



Production Ladder

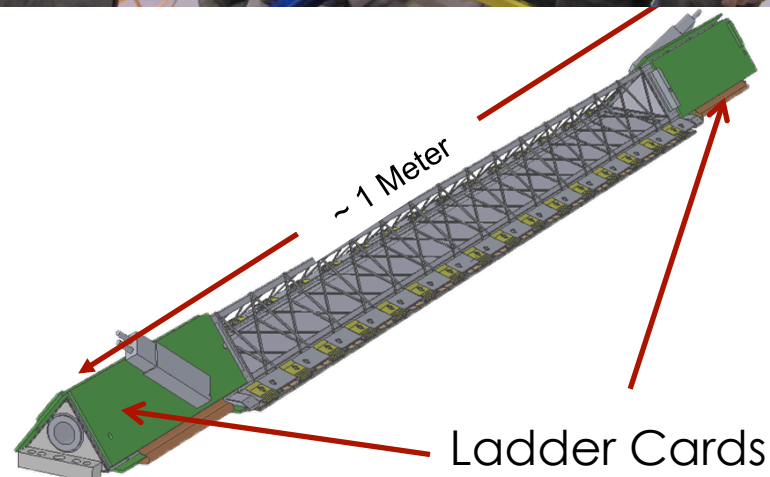
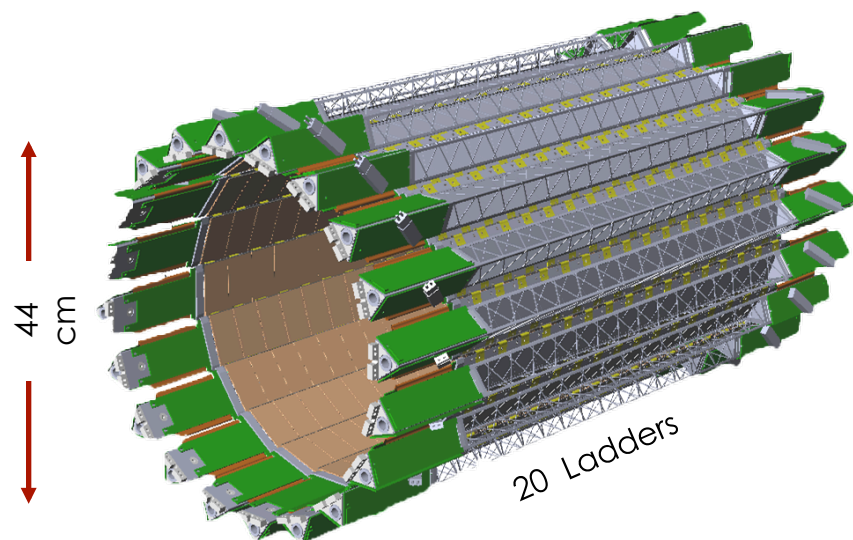
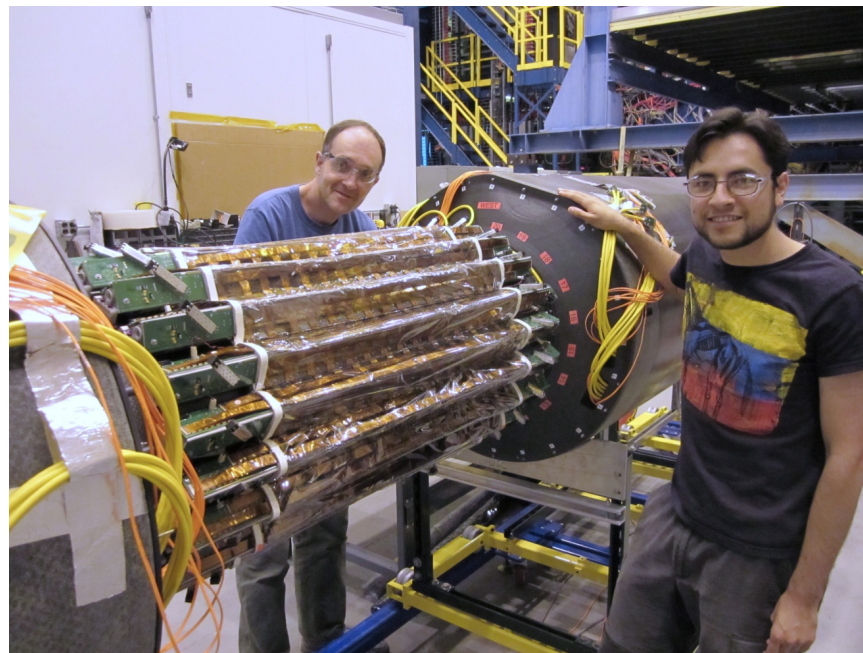
S:N  $> 20:1$

$>99.5\%$  live and functioning channels

# Silicon Strip Detector (SSD)

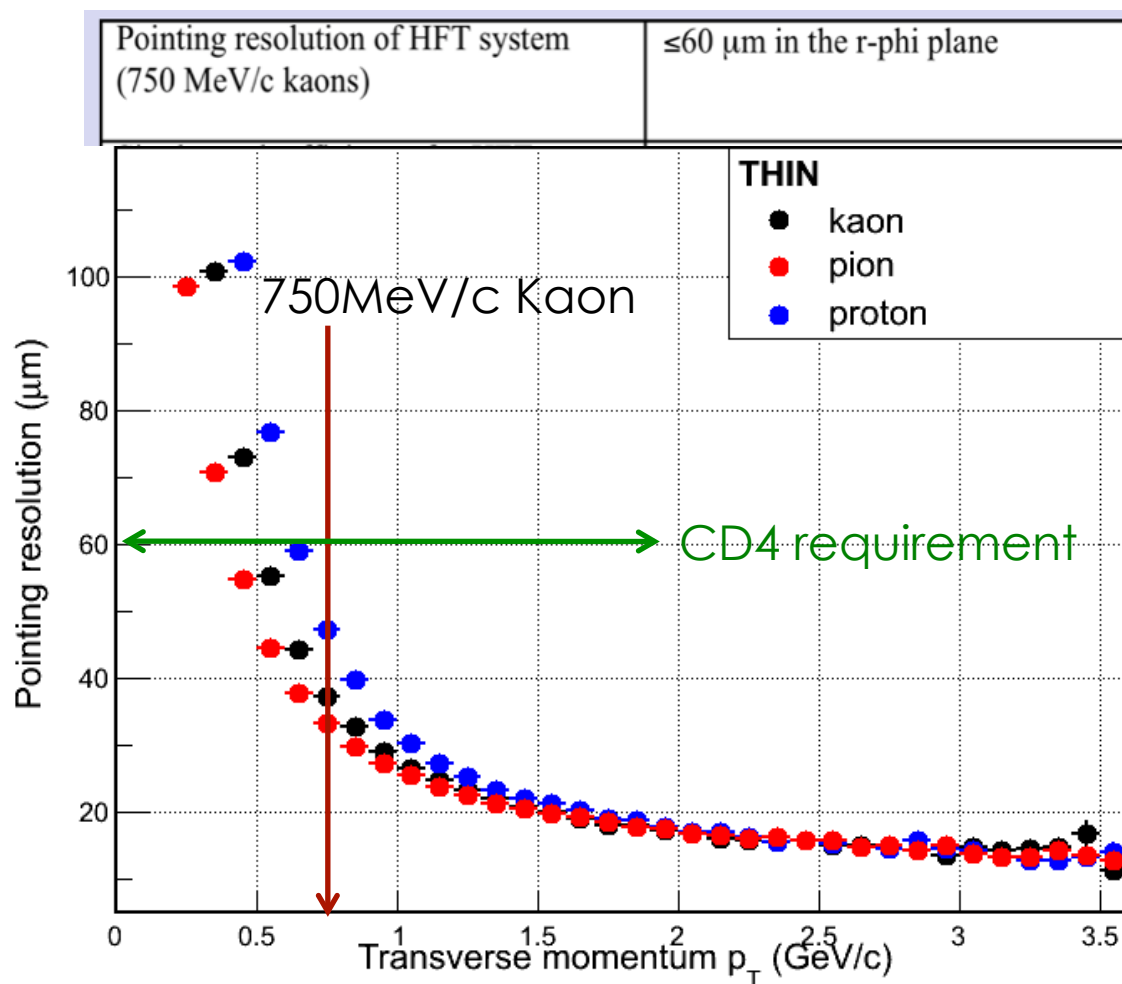
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- Existing detector
- 20 ladders at 22 cm
- Double sided Silicon with total ~400k strips
- New faster readout ~15% at 1 KHz limited by original detector hybrids



# Expected track-pointing resolution

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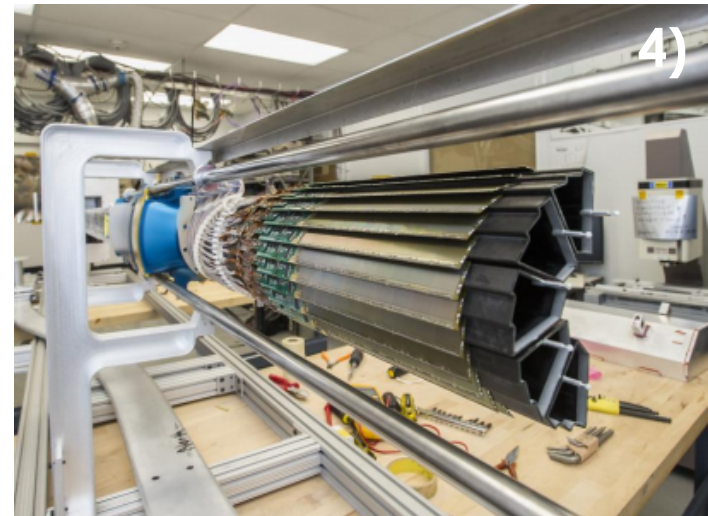
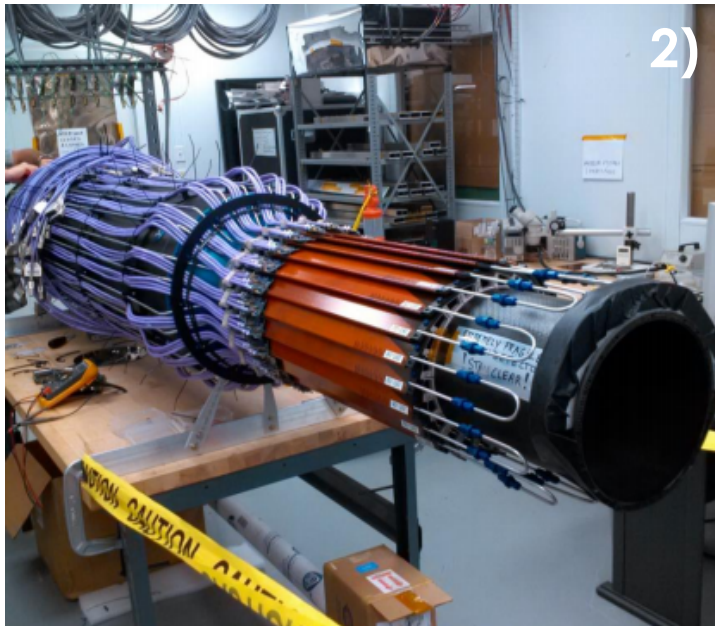
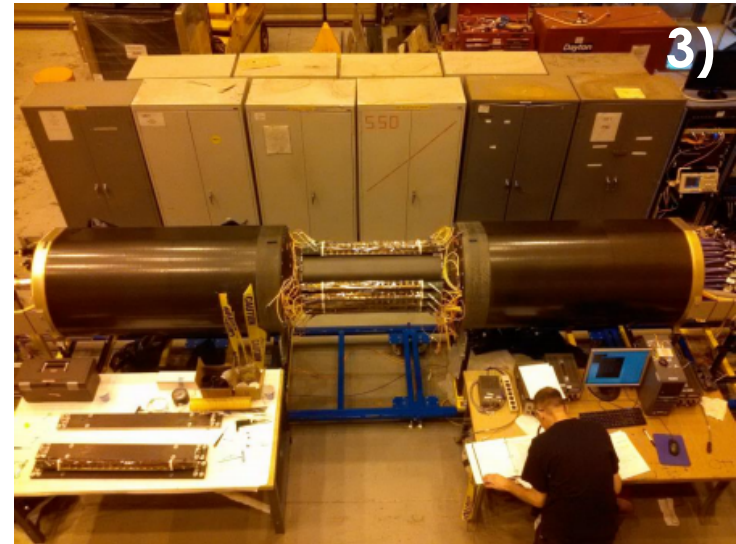
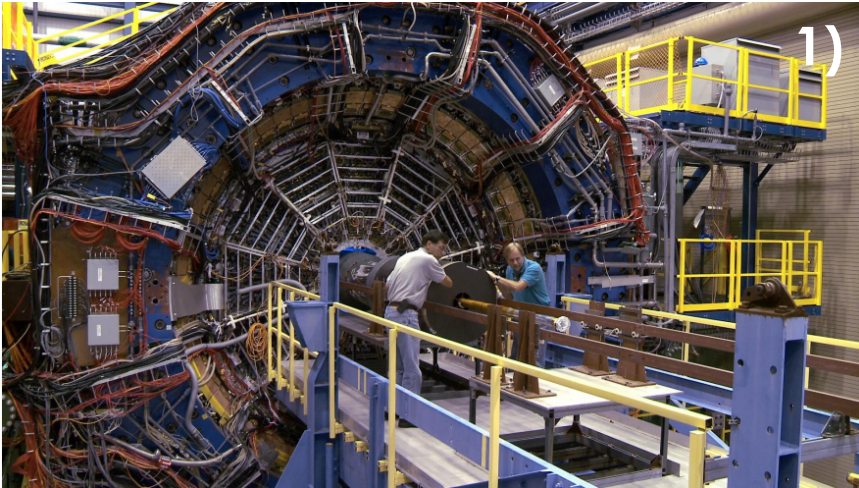


**GEANT:** Realistic detector geometry + Standard STAR tracking including the pixel pileup hits at RHIC-II luminosity

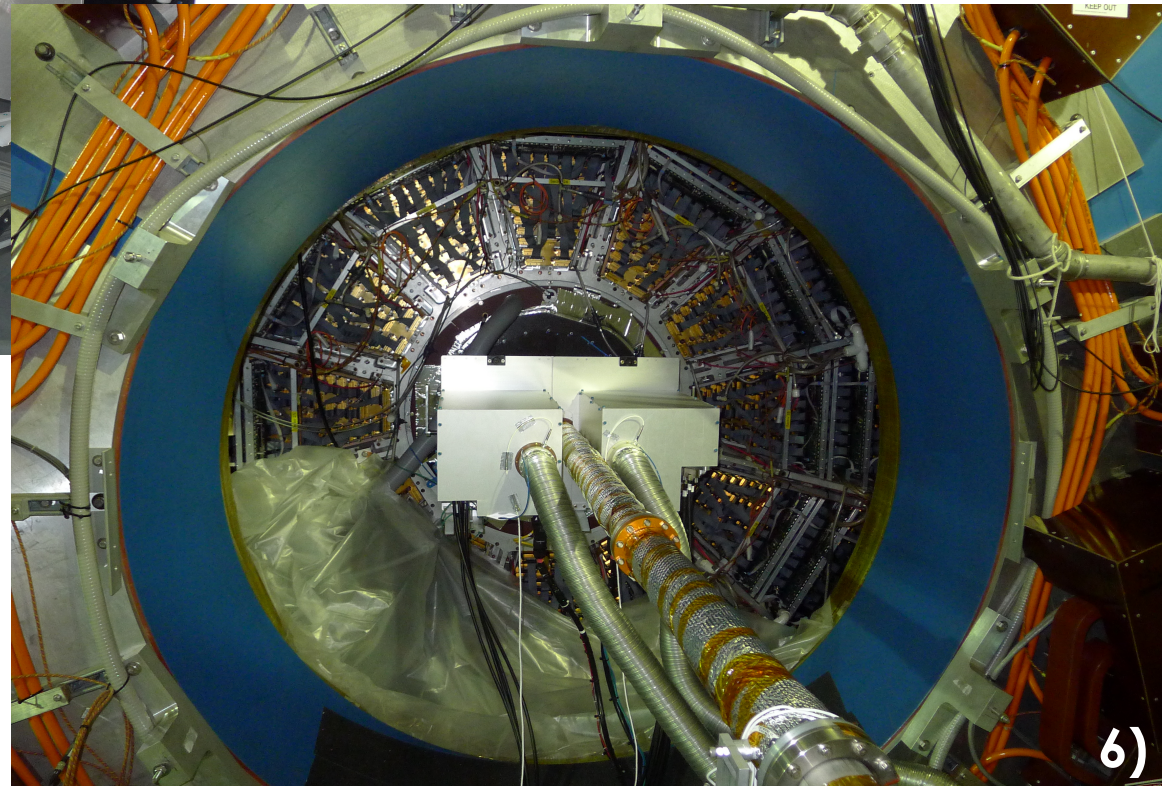
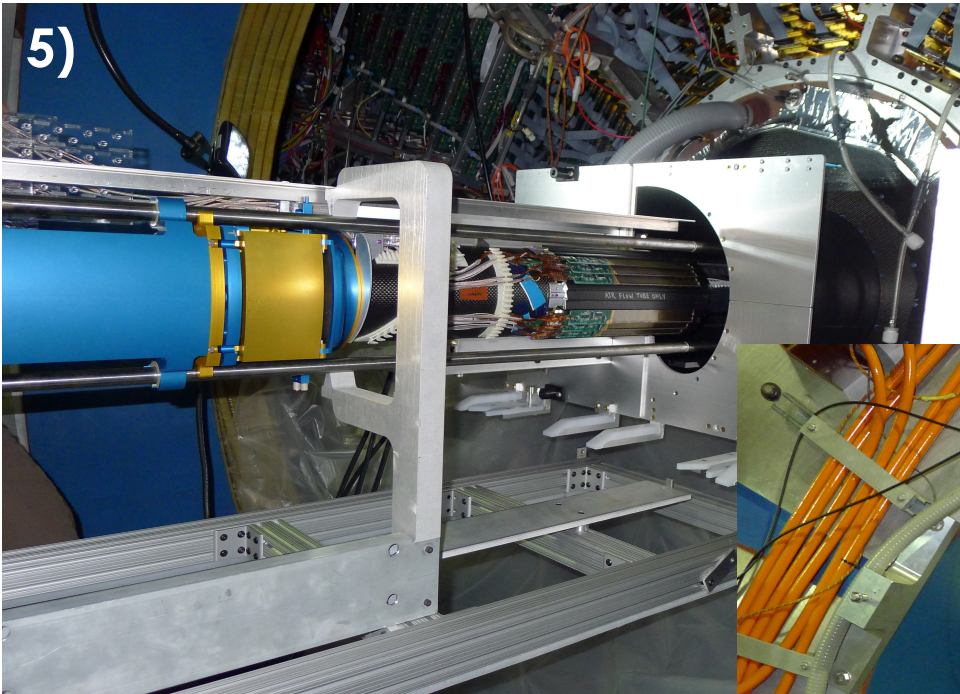


# Integration of the HFT in STAR

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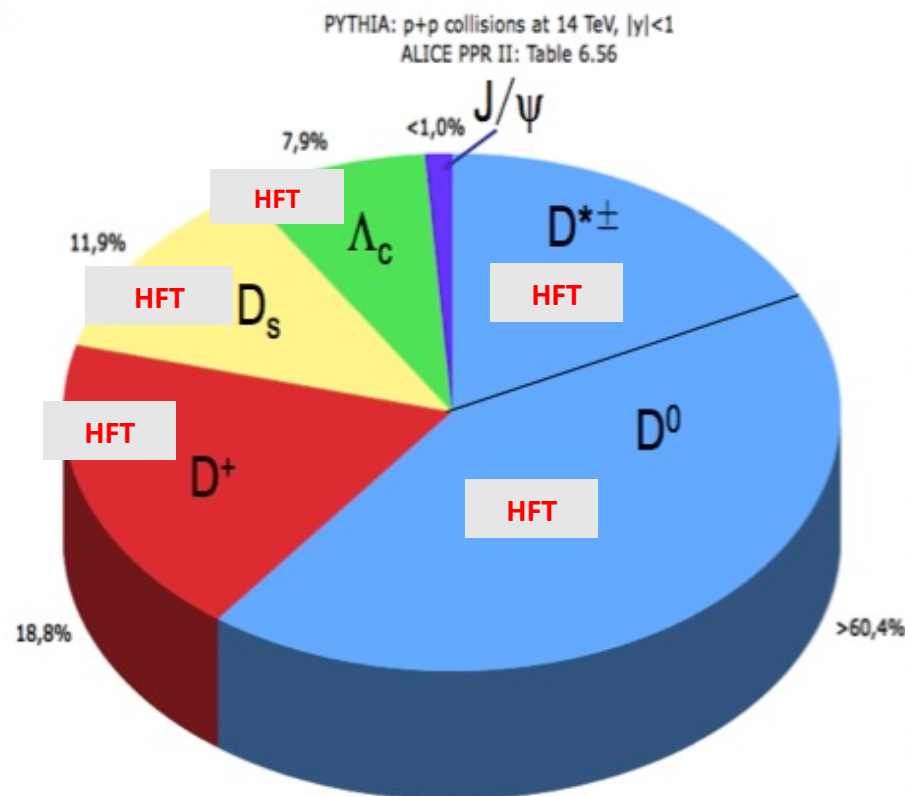


PXL being pushed in and after installation in the East end of STAR

# HFT physics

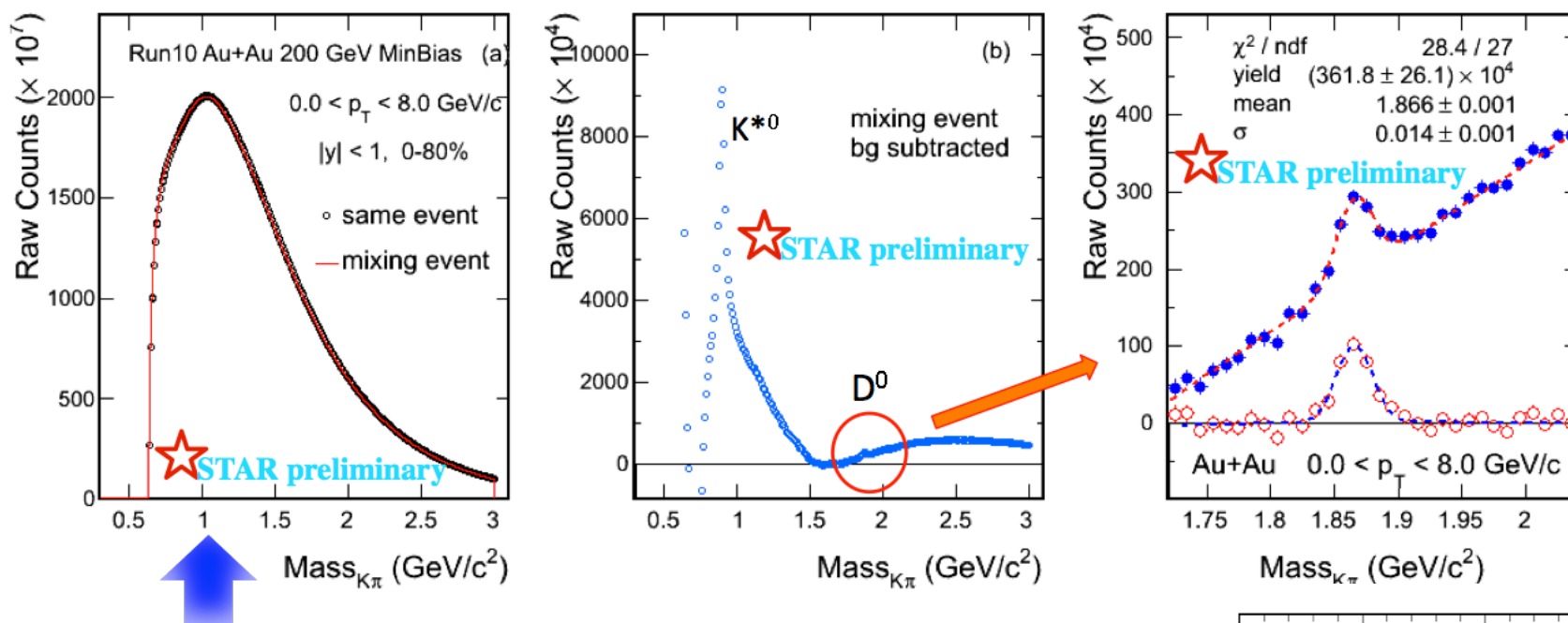
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- HFT can provide hermetic coverage of full charm sector
- Need for precision charm  $R_{CP}$  and  $R_{AA}$  analyses with fast turn-around times
- Detector capabilities better than LHC
- Strength in lower  $p_T$



# Charm yield, $R_{cp}$ and $R_{AA}$

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- Large combinatorial background using primary tracks to reconstruct D $^0$
- Much better S/B ratio with displaced vertex from HFT but still a challenge

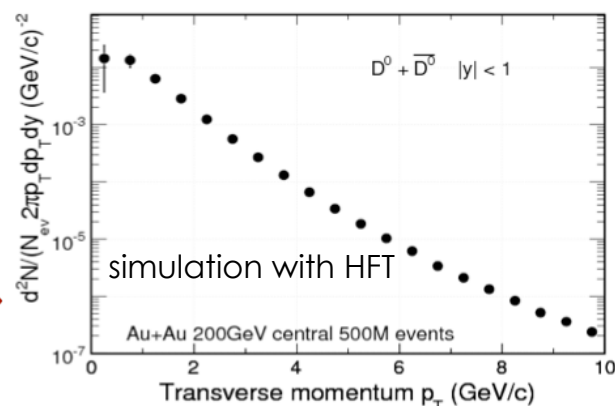
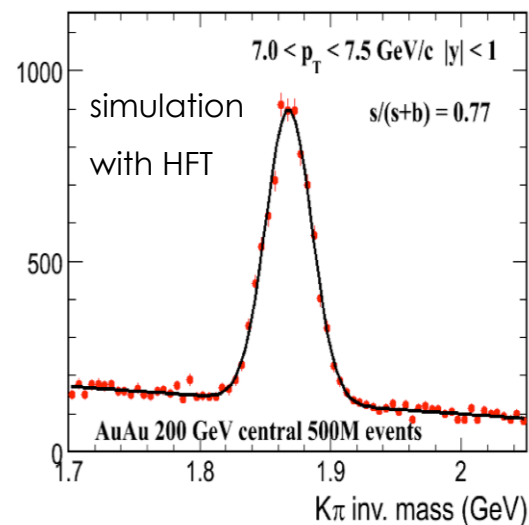
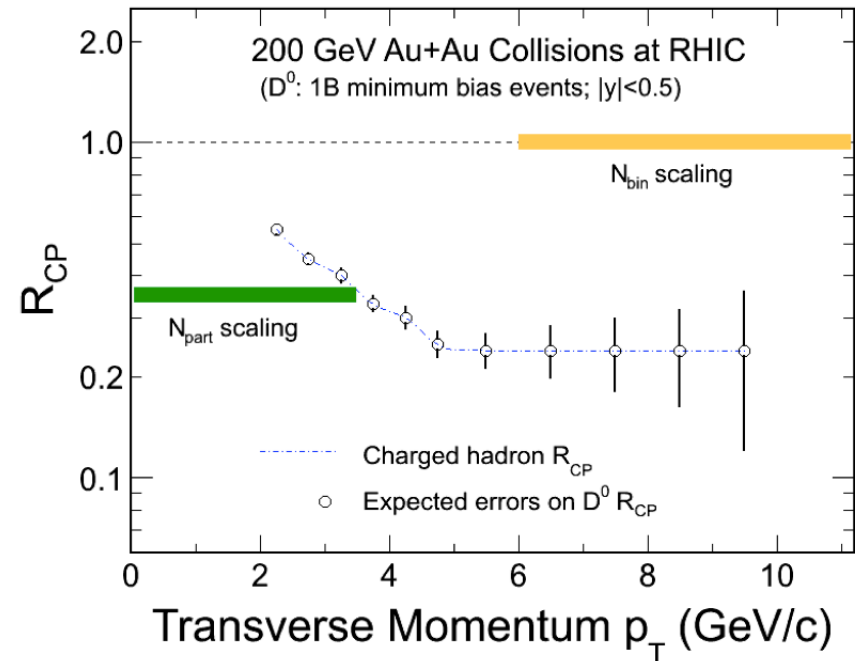
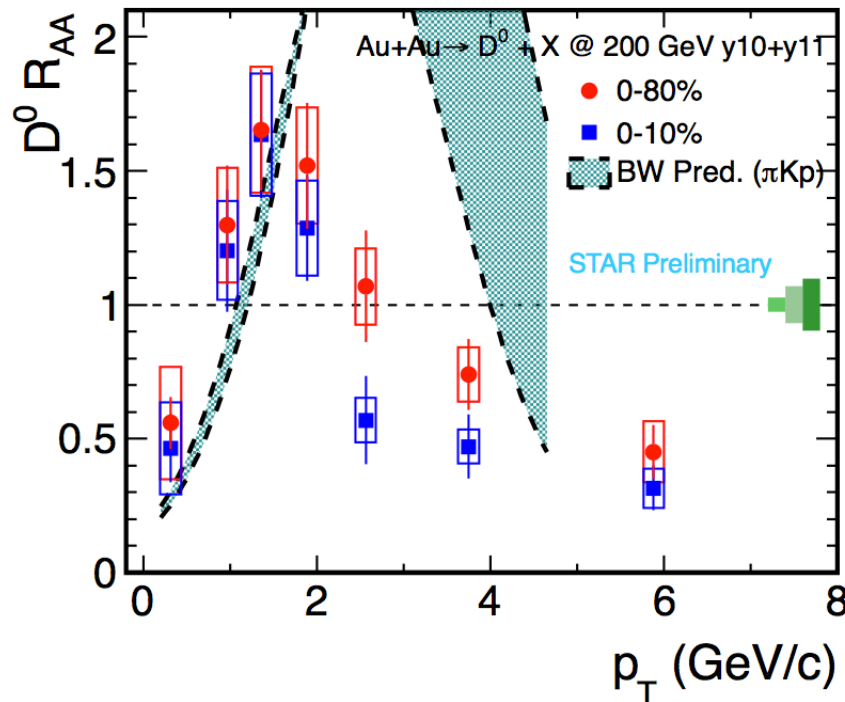


Figure 5: Estimated statistical accuracy for reconstructed D $^0$  spectra. Errors shown are only.



# Charm yield, $R_{CP}$ and $R_{AA}$

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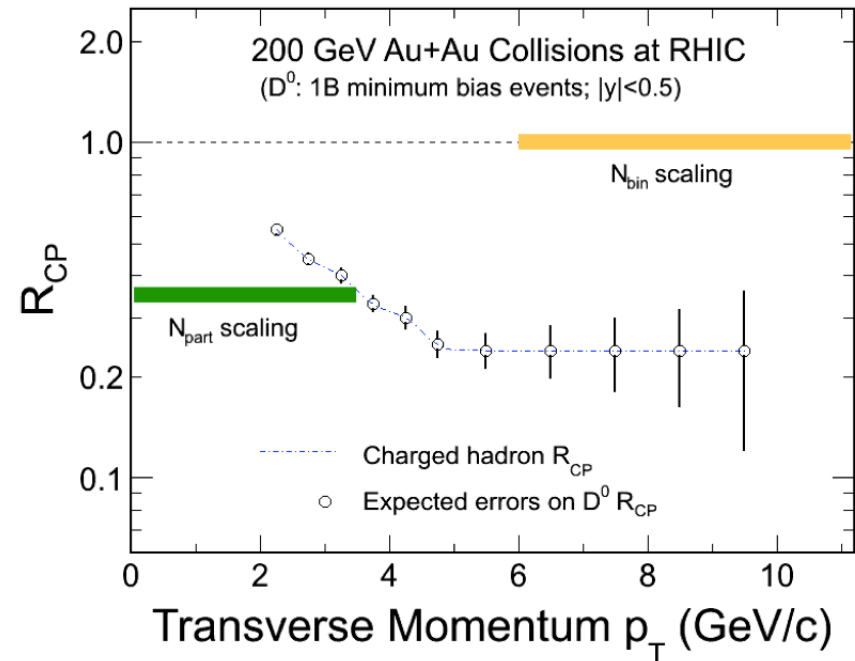
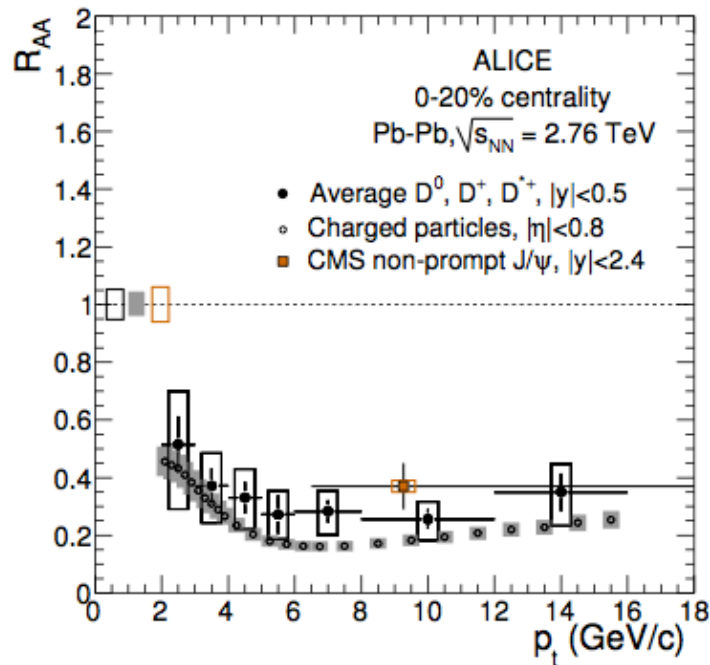


- Much better precision with HFT than current STAR measurements
- Low radiation length enable reconstruction of  $D^0$  with  $p_T$  starting from  $\sim 0$ , enabling charm total cross section measurement.



# Charm yield, $R_{CP}$ and $R_{AA}$

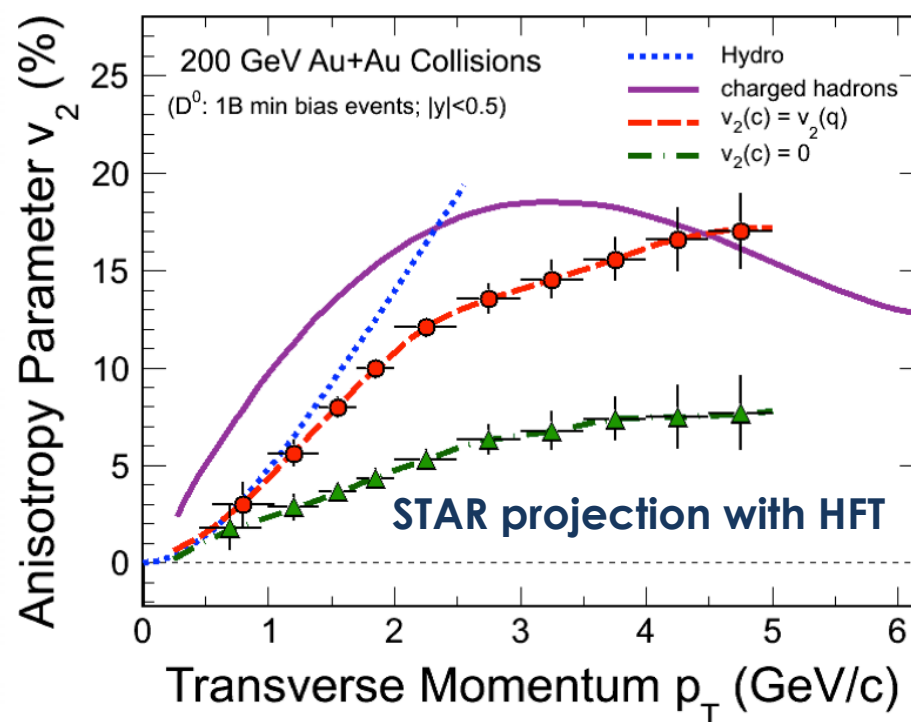
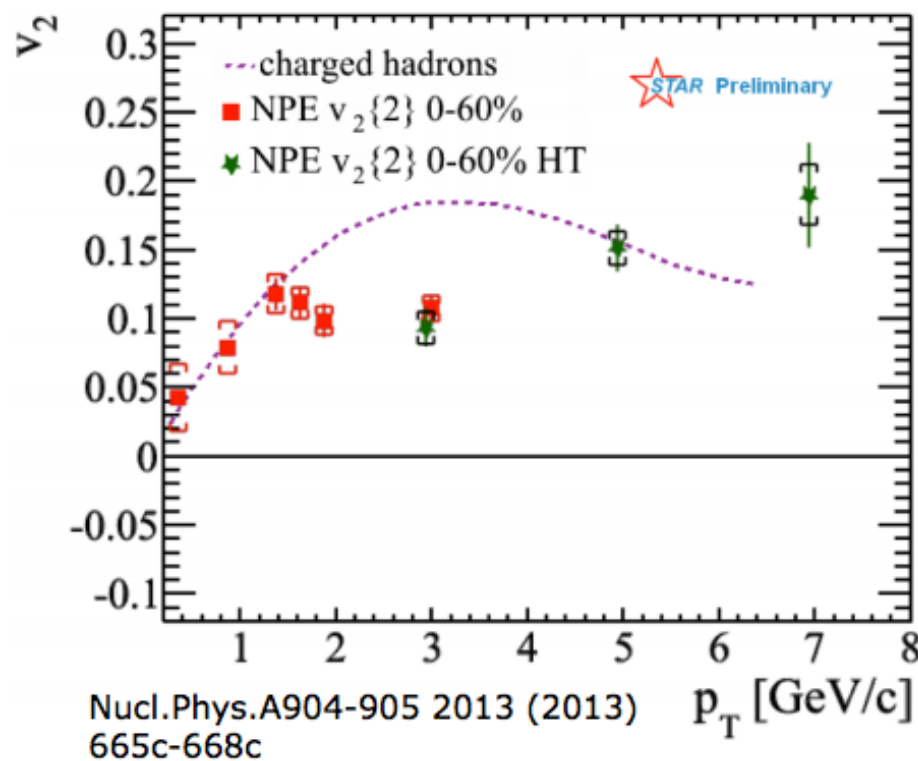
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- Probe possible different medium property with different collision energy.
- Low radiation length enable reconstruction of  $D^0$  with  $p_T$  starting from  $\sim 0$ , enabling charm total cross section measurement.

# Charm flow

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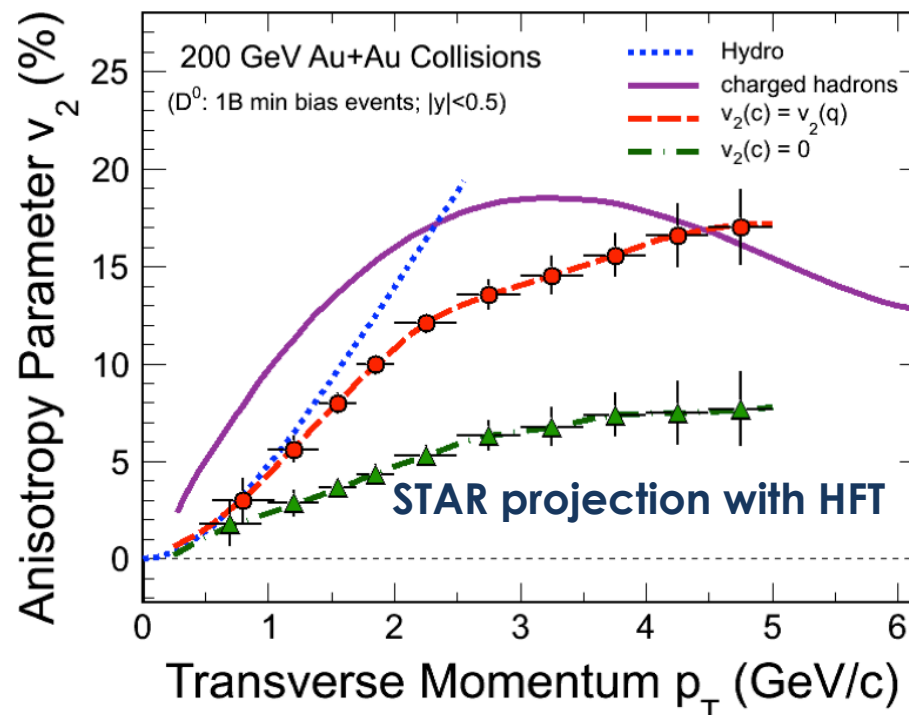
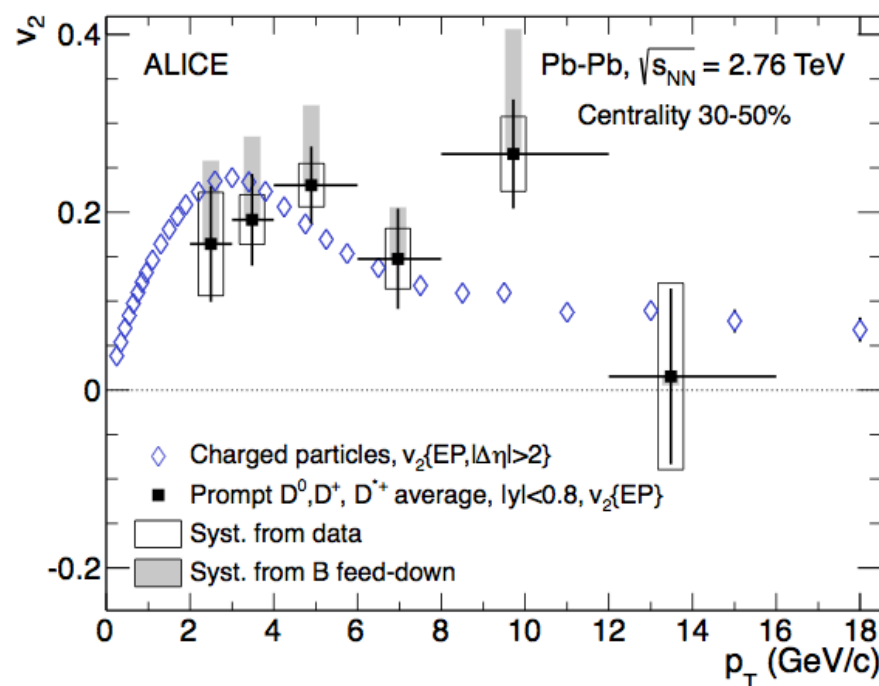


- Charm collectivity ➔ light flavor thermalization
- $D^0 v_2$  is a more direct measurement of charm flow than non-photon electron  $v_2$ .
- With HFT STAR is able to measure  $D^0 v_2$  at low  $p_T$  region, which is sensitive to charm flow



# Charm flow

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- Charm collectivity  $\longrightarrow$  light flavor thermalization
- $D^0 v_2$  is a more direct measurement of charm flow than non-photon electron  $v_2$ .
- Measurements at both LHC and RHIC will explore the change of media properties with energy.

- Overview of the STAR HFT upgrade
- The PXL detector will achieve a new standard in low radiation length vertex detectors
- The prototype run of the heart of HFT, the PIXEL system, was very valuable (next talk by M. Lomnitz)
- The final PXL detector along with the rest of the HFT upgrades have been installed for Run-14
- Together with the LHC data we expect to get new insights in the study of QGP